CONTROLLED ATMOSPHERE TREATMENTS FOR CONTROL OF TROPICAL PESTS IN STORAGE AND STRUCTURES

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Recent regulatory pressures affecting the use of methyl bromide have stimulated interest in the use of controlled atmosphere treatments, using carbon dioxide and/or nitrogen, for control of storage and structural insect pests. The possibility of quarantines against these insects intensifies the need to identify alternative treatments.

In Florida, where sweetpotato weevils, *Cylas formicarius elegantulus* (Summers), can cause up to 55% crop loss when sweet potato harvests are delayed, methyl bromide was not a viable postharvest alternative, as it was known to cause tissue necrosis followed by fungal decay. We investigated the effect of low nitrogen and elevated carbon dioxide levels on weevil mortality and crop quality. Previous experiments demonstrated an inhibition of wound periderm formation (the protective layer on the sweet potato surface which forms during the curing process) and subsequent decay below 8% O_2 (Delate & Brecht, 1985; Delate, 1986); thus, treatments for uncured sweet potatoes were selected at or above this concentration. Lowering the oxygen concentration from 21% to 8% O_2 had no effect on weevil mortality until additional carbon dioxide was provided. The treatment of 8% O_2 plus 60% CO_2 reduced the rate of weevil emergence from infested roots to 1.8% of the control after 1 wk at 30°C and 95% RH (curing conditions) and 1 wk in air. Treatments of 4% O_2 plus 60% CO_2 and 2% O_2 plus 40-60% CO_2 completely prevented emergence of sweetpotato weevils from infested roots (Table 1); these treatments would be feasible only for use with previously cured sweet potatoes (Delate et al., 1990).

In Hawaii, alternative postharvest control techniques, including controlled atmosphere treatments, cold/heat treatments and composting of infested macadamia husks and nuts, were evaluated for control of *Hypothenemus obscurus* (F.) (Coleoptera: Scolytidae), the tropical nut borer, in macadamia nuts. Exposure of infested nuts "in-husk" to ≥95% CO_2 at ambient temperatures (24-30° C) for 6 d resulted in 97.3% mortality of adult beetles. All adult insects were killed at this exposure time and concentration when nuts were husked before treatment. A 14 d treatment of ≥95% N_2 was required for 100% mortality in unhusked nuts (Figure 1).

A cold treatment of 7° C for at least 14 d was required to provide 100% adult *H. obscurus* mortality in nuts in-husk. A 7 d heat treatment at 45° C also provided 100% mortality (Table 2). Composting infested culled macadamia nuts and husks with urea in a wooden bin system resulted in 100% mortality in 14 d while composting with poultry manure resulted in

100% mortality in 7 days. A more rapid mortality was obtained in a closed vs. open composting system (drum vs. windrow pile) (Delate et al., 1994).

Formosan subterranean termites, *Coptotermes formosanus* Shiraki, are the most destructive structural pest in Hawaii and the tropics. We exposed termites from three termite colonies to ≥95% CO_2 and obtained significant mortality at 24 hr; a 60 hr exposure was required for complete mortality (Table 3). Exposure to 50% CO_2 for 60 hr resulted in approximately 70% termite mortality, while complete mortality was recorded after 120 hr. When termites were sealed in wooden blocks to simulate fumigation of buildings, a 72-96 hr exposure of ≥95% CO_2 was necessary for complete control (Table 4). A limited study with *Cryptotermes brevis* (Walker) suggested that this drywood termite is also susceptible to carbon dioxide fumigation, although slightly longer exposures may be required than with C. formosanus. From these studies, it appears that carbon dioxide is a viable alternative to organic fumigants for vault fumigation of termite-infested materials, and may also be applicable to larger-scale fumigations to control structural pests (Delate et al., 1994).

References

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Table 1. Percentage of sweetpotato weevils completing development in sweet potato roots at 25°C and 75% RH after exposure to controlled atmospheres at 30°C and 95% RH for 1 wk

Treatment ($\% O_2$: $\% CO_2$)	Percentage completing development[z]
21:0 (Control)	100 ± 0e
8:30	73.4 ± 9.3d
8:40	54.3 ± 7.5c
8:50	11.8 ± 2.6b
8:60	1.8 ± 0.3a
4:40	1.7 ± 1.0a
4:60	0 ± 0a
2:40	0 ± 0a
2:60	0 ± 0a

[z]Data are average percentage of emergence and SD relative to emergence from control sweet potatoes held continuously in air. Means followed by the same letter are not significantly different ($P \leq 0.05$; Duncan's multiple range test, SAS Institute).

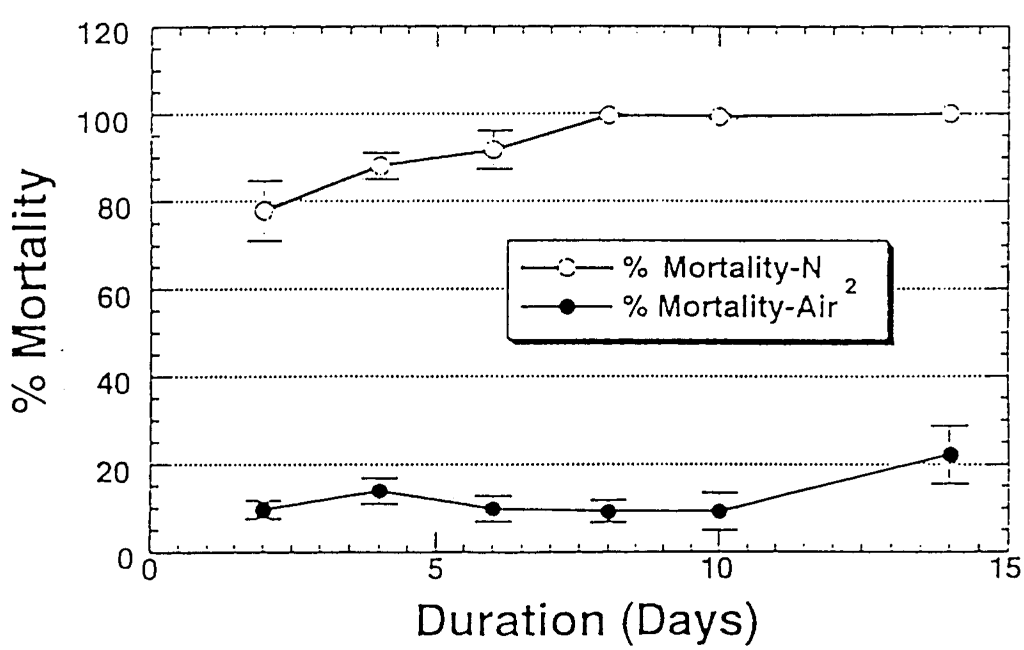

Figure 1. *H. obscurus* mortality in CA (nitrogen) and control

Table 2. Average percent mortality of *H. obscurus* in macadamia nuts after cold/heat treatments

Treatment	Duration	% Mortality	Control Mortality	Corrected Mortality
2°C	24 hr	38.0 ± 3.1	7.4 ± 1.3	33.0
4°C	24 hr	39.5 ± 1.7	8.0 ± 1.9	34.2
7°C	24 hr	27.9 ± 4.7	6.7 ± 1.1	22.7
7°C	48 hr	63.7 ± 2.5	10.1 ± 0.8	59.6
7°C	7-d	89.3 ± 5.6	10.9 ± 1.2	87.9
7°C	14-d	99.6 ± 0.4	9.8 ± 0.4	99.6
10°C	24 hr	29.9 ± 3.6	10.6 ± 2.7	21.6
10°C	48 hr	52.9 ± 2.1	10.8 ± 1.2	47.2
10°C	7-d	60.8 ± 10.2	9.5 ± 1.4	56.8
10°C	14-d	97.8 ± 1.1	10.4 ± 1.0	97.5
13°C	7-d	39.6 ± 4.0	12.2 ± 2.1	31.2
13°C	14-d	58.1 ± 3.8	12.7 ± 2.8	52.0
35°C	24 hr	52.9 ± 9.7	9.0 ± 2.3	48.2
35°C	48 hr	57.7 ± 2.8	9.2 ± 0.4	53.4
35°C	7-d	89.0 ± 9.5	11.2 ± 1.1	87.6
35°C	14-d	100 ± 0	9.6 ± 0.6	100
45°C	24 hr	87.6 ± 12.4	8.6 ± 0.7	86.4
45°C	7-d	100 ± 0	10.2 ± 0.5	100

Table 3. Mortality of *C. formosanus* termites 24 hr after exposure to ≥95% CO_2 for intervals of 24-60 hr.

Termite Colony	24 hr-CO_2	24 hr-Control	48 hr-CO_2	48 hr-Control	60 hr-CO_2	60 hr-Control
A	71.1 ± 1.3a	1.1 ± 1.5b	95.6 + 1.5ab	1.1 ± 1.5c	100 ±0a	0 ± 0b
B	56.7 ± 11.1a	0 ± 0b	82.2 ± 14.8b	1.1 ± 1.5c	100 ± 0a	0 ± 0b
C	50.0 ± 14.5a	1.1 ± 1.5b	100 ± 0a	1.1 ± 1.5c	100 ± 0a	0 ± 0b

[z]Means within each exposure interval followed by the same letter are not significantly different (P≤0.05; ANOVA of transformed percentages; REGW multiple F test; SAS Institute).

Table 4. Mortality of *C. formosanus* termites in wooden blocks 24 hr after exposure to ≥95% CO_2 for intervals of 48-96 hr.

Termite Colony	48 hr-CO_2	48 hr-Control	72 hr-CO_2	72 hr-Control	96 hr-CO_2	96 hr-Control
A	55.6 ± 3.0b	2.2 ± 3.0c	93.3 + 0a	2.2 ± 2.2b	100 ±0a	4.4 ±3.0b
B	57.8 ± 11.9b	4.4 ± 3.0b	91.9 ± 3.0a	4.4 ± 3.0b	100 ± 0a	6.7 ± 4.4b
C	82.2 ± 7.7a	0 ± 0c	86.7 ± 0a	8.9 ± 3.0b	100 ± 0a	6.7 ± 6.7b

[z]Means within each exposure interval followed by the same letter are not significantly different (P≤0.05; ANOVA of transformed percentages; REGW multiple F test; SAS Institute).